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Dr. T. L. K. Smull, Director
Office of Research Grants and Contracts
National Aeronautics and Space Administration
Code SC
Washington 25, D. C.

Dear Dr. Smull:

This letter constitutes the semi-annual status report on the research work supported by NASA under Research Grant NsG 260-62 to the University of Arkansas entitled "Techniques of Radio Frequency Mass Spectrometry" through September 15, 1965.

ION ATTITUDE STUDY

The ion attitude study consists of two areas of investigation. The first area of interest consists of the effect on the mass spectrum of variable energy ions which correspond to apparent velocities of ions entering an orbiting ion spectrometer. Secondly, it is necessary to know the effect on the ionic mass spectrum entering an orbiting ion spectrometer at various angles or attitudes. These studies require the use of a highly uniform, nearly parallel, monoenergetic beam of ions whose energy is variable with respect to the entrance guard ring. This beam also must impinge upon the guard ring at known, variable angles.

Until recently, most of the expended effort in this laboratory was in the area of system optimization, which has resulted in a series of compromises. One such compromise involved the N_{14}^{+} sensitivity which was too low when the system variables were such as to provide minimum resonant ion transmission through the analyzer. This condition occurred when the ion energy was 10 electron volts, attitude was 90 degrees and the analyzer was set at 95% of cutoff. Although the N_{14}^{+} peak was nearly unreadable at this point, the N_{28}^{+} and argon peaks were of sufficient amplitude to provide excellent spectral data. Increasing ion energy or decreasing attitude or percent of cutoff increased the height of the N_{14}^{+} peak somewhat, but it still remained low.

An attempt to provide a 2-1/4 inch diameter ion beam of constant density was approximated as closely as possible. This condition is demonstrated in Fig 1 in which the abscissa represents a cross-sectional diameter of the ion beam divided into six annuli with the center annulus or collector represented by the number 1. The ordinate represents the ion current collected per unit area on each of the six annuli and normalized with respect to the current per

unit area as collected on the first or center annulus. This figure shows the beam of cross-sectional density of the least deviation that has been obtained with the present configuration. The portion of greatest deviation from constant density occurred in the center of the beam and was centered along the axis of the ion gun. Since the analyzer was stationary, the longitudinal axis of the system was coincident at all times with the axis of the analyzer tube. The angle between the ion gun axis and the longitudinal axis with respect to the center of the analyzer entrance or the guard ring determined the ion beam attitude. Since the portion of the greatest deviation of the ion beam impinged on the guard ring at the same point from all angles, the deviation had no adverse effects on the data. The vertical lines in Fig 1 represent the actual 1-5/16 inch entrance diameter to the ion spectrometer.

When the ion energy is varied the ion current per unit area in the plane of the guard ring changes as a result of a change in the electrostatic forces of attraction between the ions and the guard ring. Therefore, calibration data will have to be provided to compensate for changes in ion current per unit area reaching the analyzer. This calibration data will permit ion energy to be varied without changing the amount of ion current to the analyzer. The calibration data are obtained by placing a solid collector, having the same diameter (1-5/16 inches) as the analyzer tube, 1/16 inch in front of the first pulling out grid. The collector is tied to an electrometer and then to the same voltage supply as the first pulling out grid. The variation of the ion current on the collector with respect to ion energy and attitude represents the calibration data. Theoretically, when the final data is compensated and there are still significant differences in sensitivities with respect to ion energy, these differences may be attributed to some type of discrimination caused by the fact that the ions entering the analyzer possess different velocities. Peak height information included in this report has not been compensated and the data included are not in final form.

To date data have been obtained for argon and work will be performed with nitrogen and neon in the near future. The system parameters, under which the argon data were obtained, are referred to as standard conditions. They are as follows:

Sample - Argon

$P\mu$ = .1μ Torr	V_{l_2} = -100 volts
P_o = 5μ Torr	V_{l_3} = -160 volts
V_e = -50 volts	V_D = -5 volts
I_e = .65 mA	V_g = true ground
V_r = -172 volts	V_B = 36 volts
V_{l_1} = -80 volts	V_{RF} = 6 volts r.m.s.
	V_{co} = 41 volts

A Glossary of Terms is presented in Table 1 and it provides an explanation of what these symbols physically signify. The system variables involve ion beam attitude, ion energy, percent cutoff, and mass (i.e. argon, nitrogen and neon). Ion beam attitude was set at five values, 0, 30, 60, 75 and 90 degrees. The ion energy was varied at 3 electron volt increments between 10 and 25 electron volts. The percent cutoff was set at nine appropriately spaced values. To date the study has been restricted to argon. In order to obtain all possible combinations of the system variables, 270 mass spectrum scans were required. A complete mass spectrum scan up to mass 44 for each of the 270 sets of system variables was required to obtain all resonant and harmonic peak height, peak position and resolution data simultaneously and with the same degree of accuracy. Since each scan required 10 minutes and the data for one angle consisted of 54 scans, approximately twelve hours were required to complete the entire assembling of data. With five values of attitude, five days were required to complete the measurements on argon. These measurements will permit evaluation of the effect of these system variables on the harmonic and resonant spectral parameters: baseline shift, cutoff, efficiency, peak height, peak position, resolution and stability.

The remainder of the figures, compiled from the data for argon and representing 90% cutoff only, is described below. Data have been obtained for other values of percent of cutoff but have not been evaluated to date.

A family of curves of ion energy vs argon sensitivity taken at various angles is shown in Fig 2. These curves demonstrate the fact that ions possessing higher energies and angles tend to collect on the conducting portion of the spectrometer walls or strike the guard ring. In addition to the above two effects, the entrance to the analyzer tends to lay in a "shadow" of the ion beam at higher angles.

The family of curves of ion energy vs peak position at various angles (cf Fig 3) demonstrates that as ion energy is increased, the accelerating potential on the analyzer that yields the greatest number of resonant ions decreases at about the same rate at all angles.

Figure 4 represents a family of curves of ion energy vs resolution taken at various angles. These curves establish the fact that at lower angles the resolution increases slightly with increasing ion energy. At higher angles the resolution varies inversely with ion energy.

Figures 5,6 and 7 are a family of curves showing ion current sensitivity of argon as a function of ion attitude measure at various ion energies. These figures show that the curve becomes S-shaped at higher energies and that the mass 40 ion current tends to drop off at higher energies and angles.

Figures 8 and 9 present plots of attitude vs peak position at varying ion energies. As would be expected, increasing ion energy shifts the peak to a lower value of accelerating potential.

Figures 10 and 11 are a family of curves of attitude vs resolution at various ion energies. These curves indicate that there is little, if any, change in resolution with respect to ion energy.

No explanation of any of the phenomena has been included in the above paragraphs which describe the graphs because more than one set of data is desired before any explanation is attempted.

The following constitutes the proposed work for the next six months.

Sensitivity, efficiency and any shift in cutoff or accelerating potential of the ion spectrometer will be studied as a function of ion energy and mass over a range of ion attitudes from zero to 90 degrees for both resonant and harmonic spectra.

Sensitivity and efficiency of the ion spectrometer will be studied as a result of changing any of the internal spectrometer tube potentials. This will be performed with all conditions, except ion attitude, external to the spectrometer constant in order to determine if the normally accepted ion spectrometer voltage values might be optimized for the analysis of ions entering at attitudes other than zero. Work in this area has already been performed with argon although all the information has not been analyzed, and this study will be extended to nitrogen and neon.

Finally, consultation service will be provided at Goddard Space Flight Center regarding any related investigation being performed there or at any contractor's site.

Sincerely yours,

M K Testerman

M. K. Testerman
Principal Investigator

MKT/ac

GLOSSARY OF TERMS

I_e -- emission current

V_e -- ionization potential

E_f -- energy of formation

V_g -- guard ring potential

V_r -- electron repeller potential

V_{l_1}, V_{l_2}, V_{l_3} -- focusing lens potentials

V_d -- ion deceleration grid

V_a -- acceleration potential

V_b -- stepdown potential

V_{rf} -- R. F. potential (rms)

V_s -- retarding potential (relative to E_f)

θ -- ion entrance angle (actual)

I_t -- total ion current

I_m --collected ion current for any given mass (sensitivity)

EFE -- I_m/I_t x 100 for pure sample

$R = M/\Delta M$ -- resolution at one-half peak height

P_μ -- ultimate pressure of system

P_o -- operating pressure

V_{co} -- cut off potential (relative to E_f)

$\%_{co}$ -- percent cutoff

Table 1

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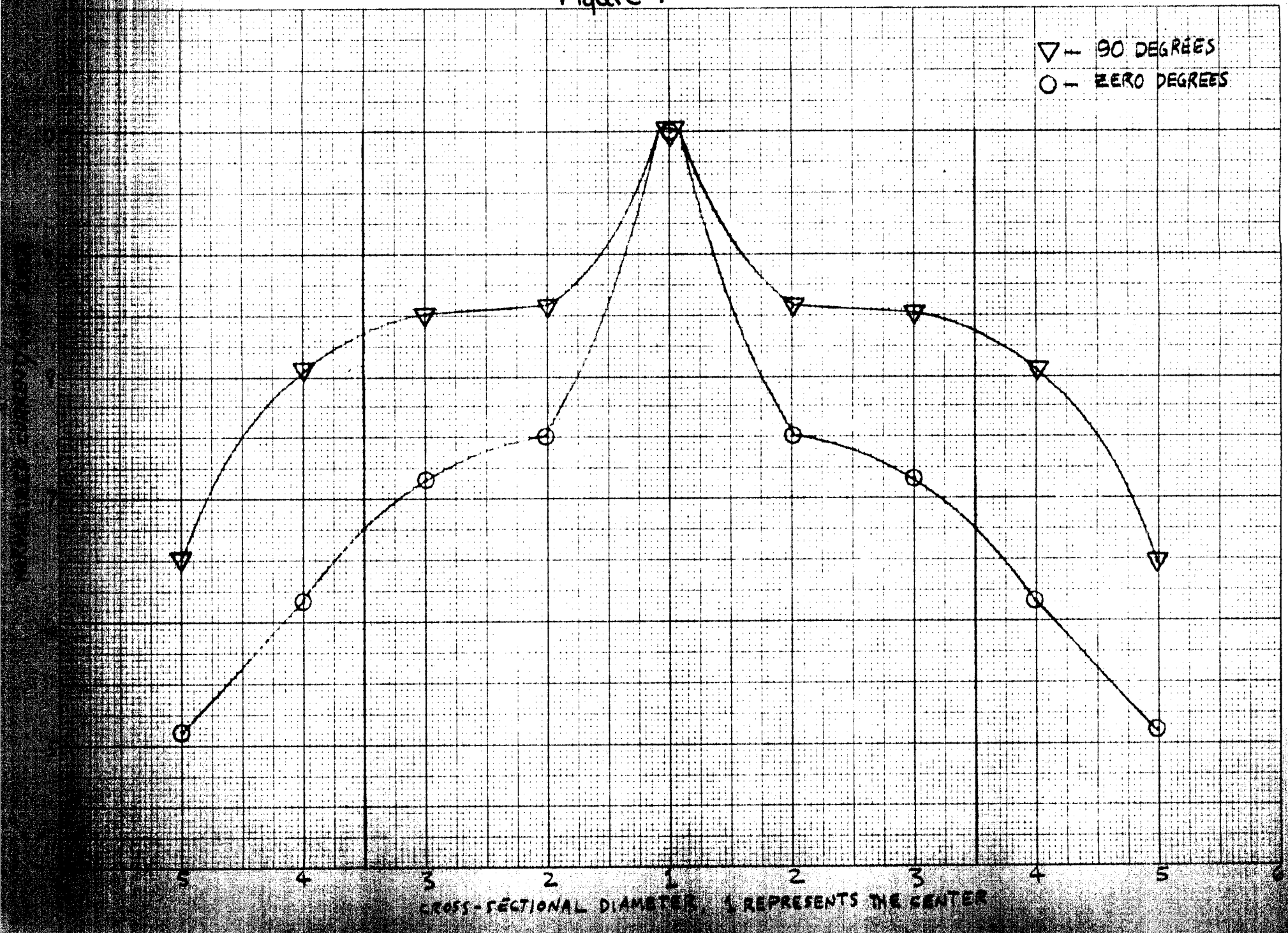
Figure 1



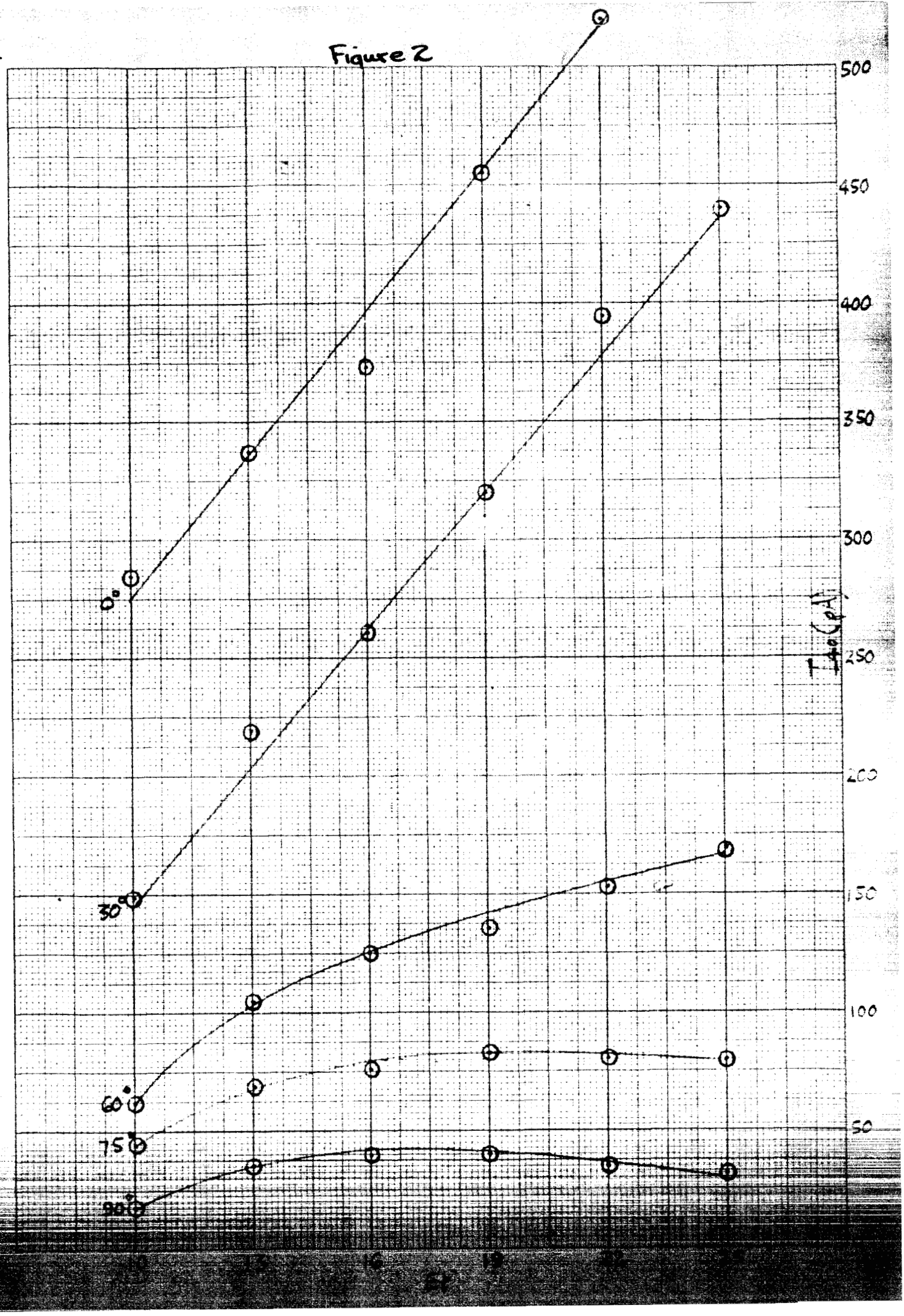


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Figure 3

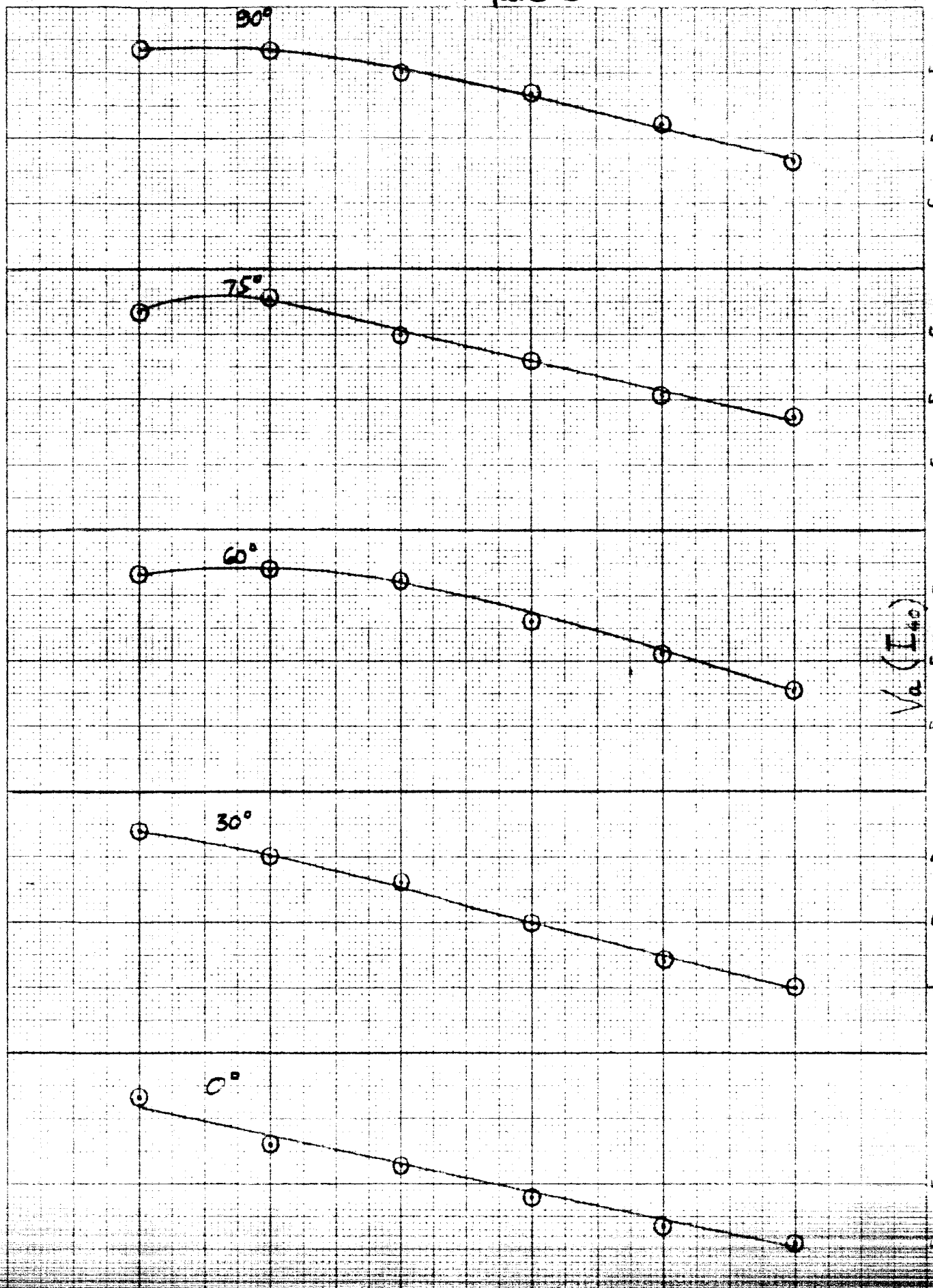

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Figure 4

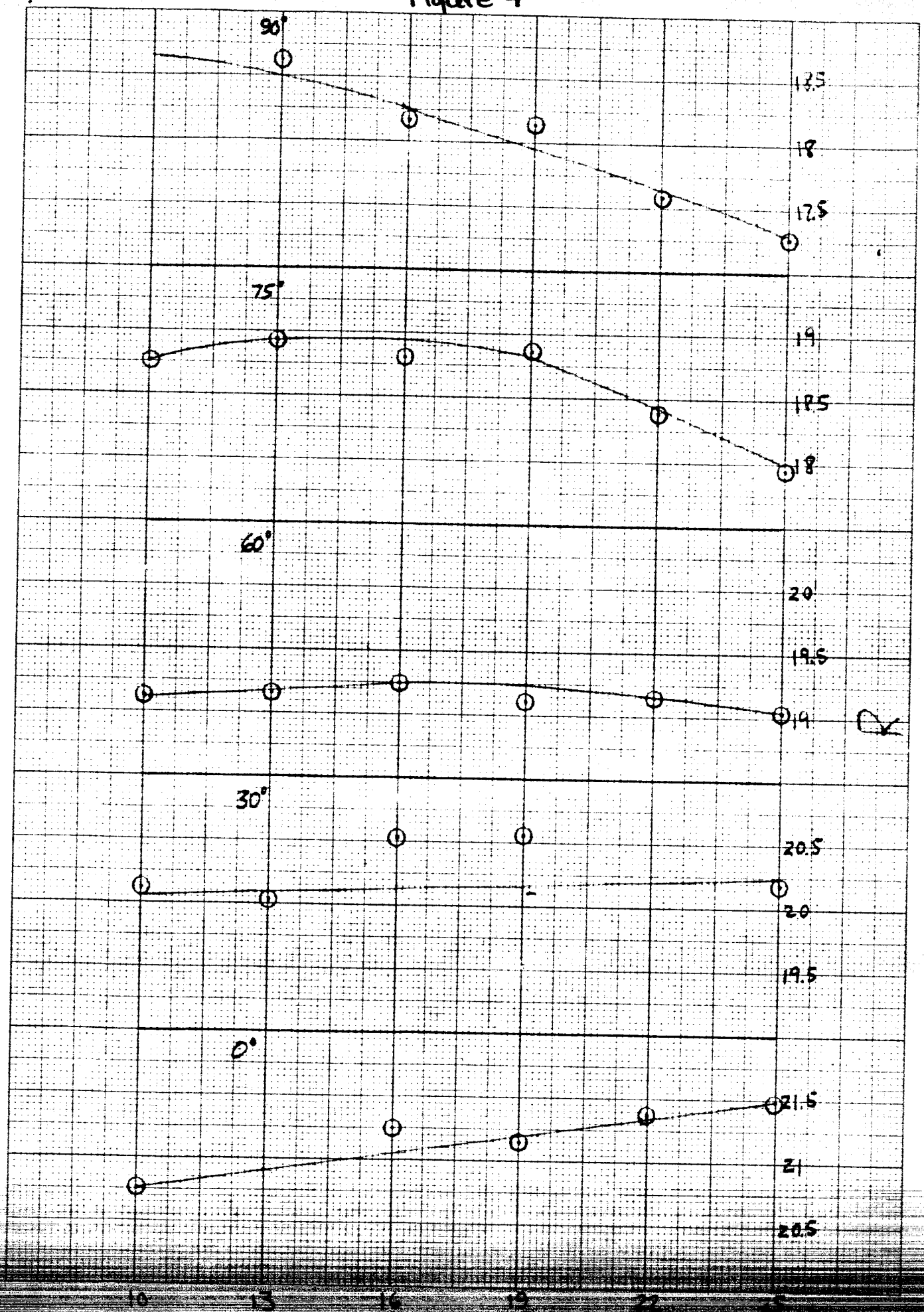

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Figure 5

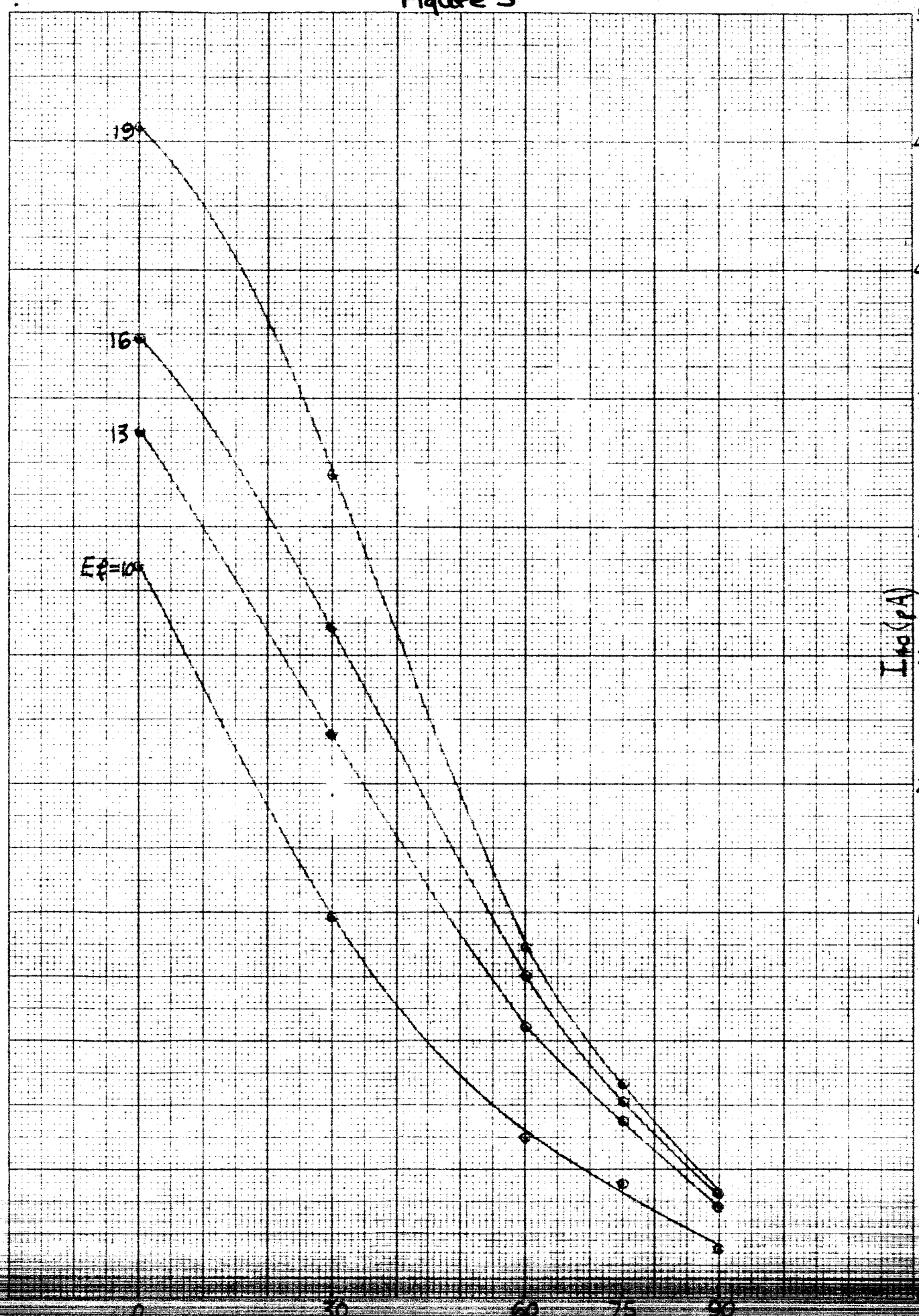

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Figure 6

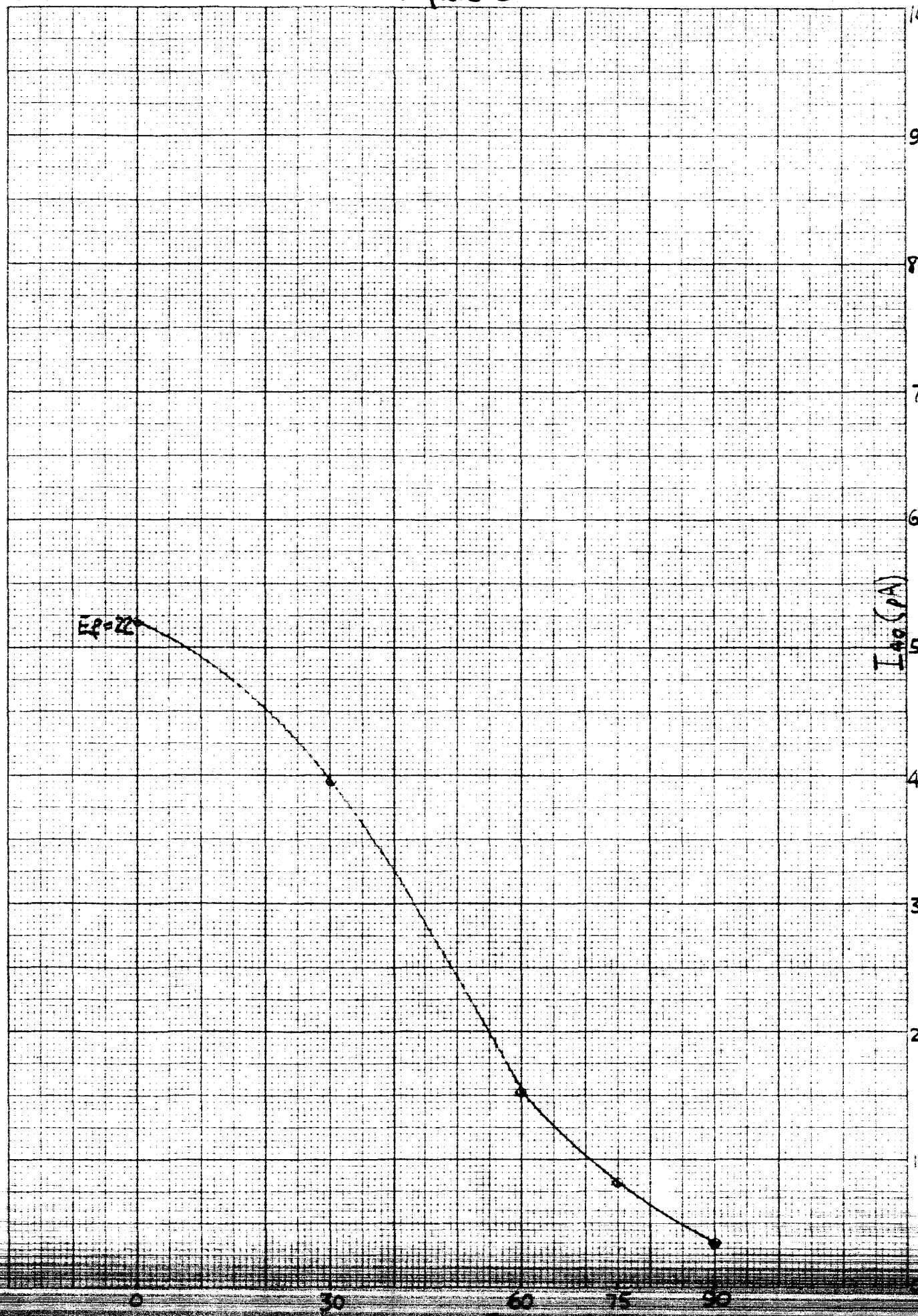

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Figure 7

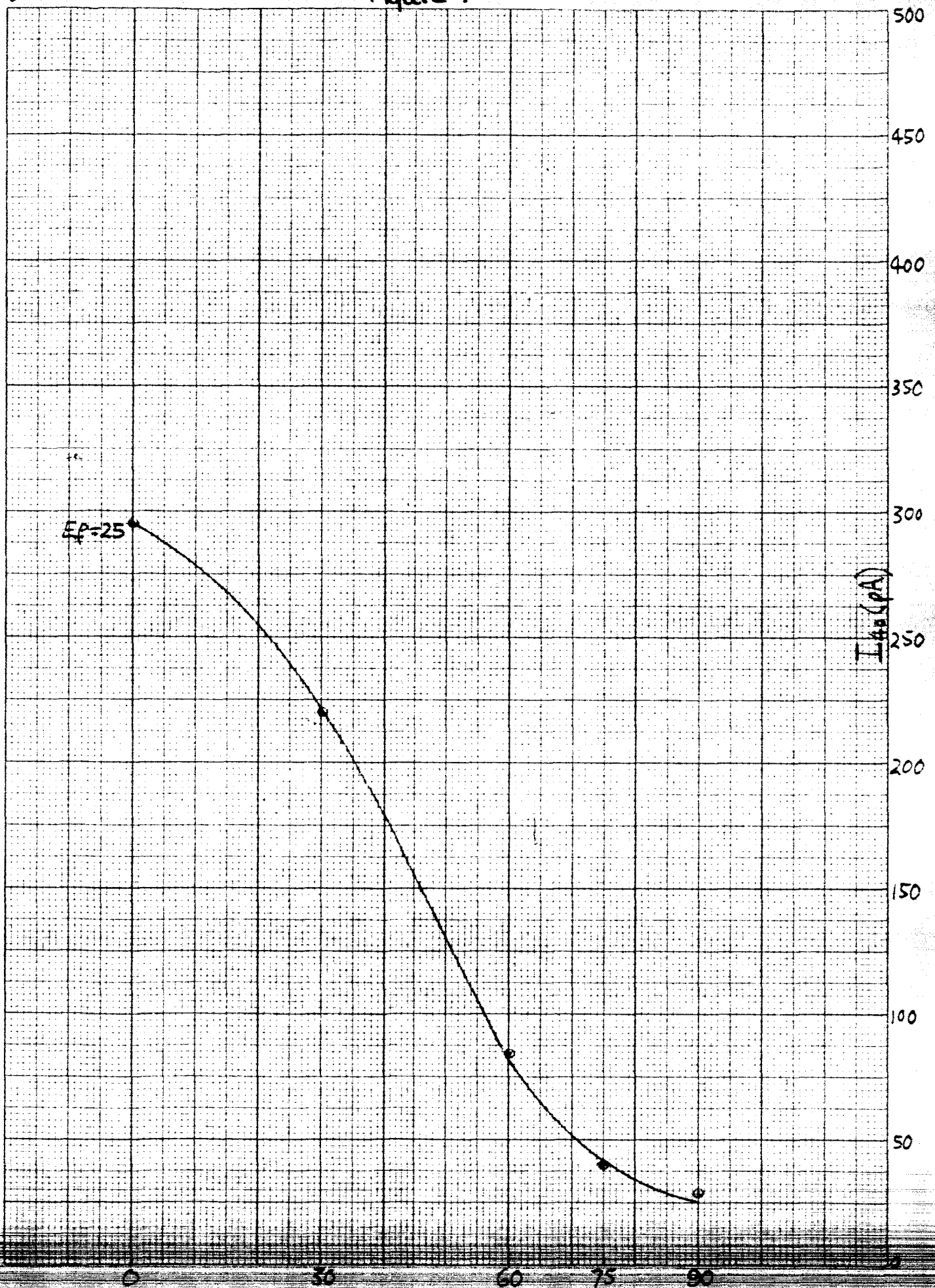

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Figure 8

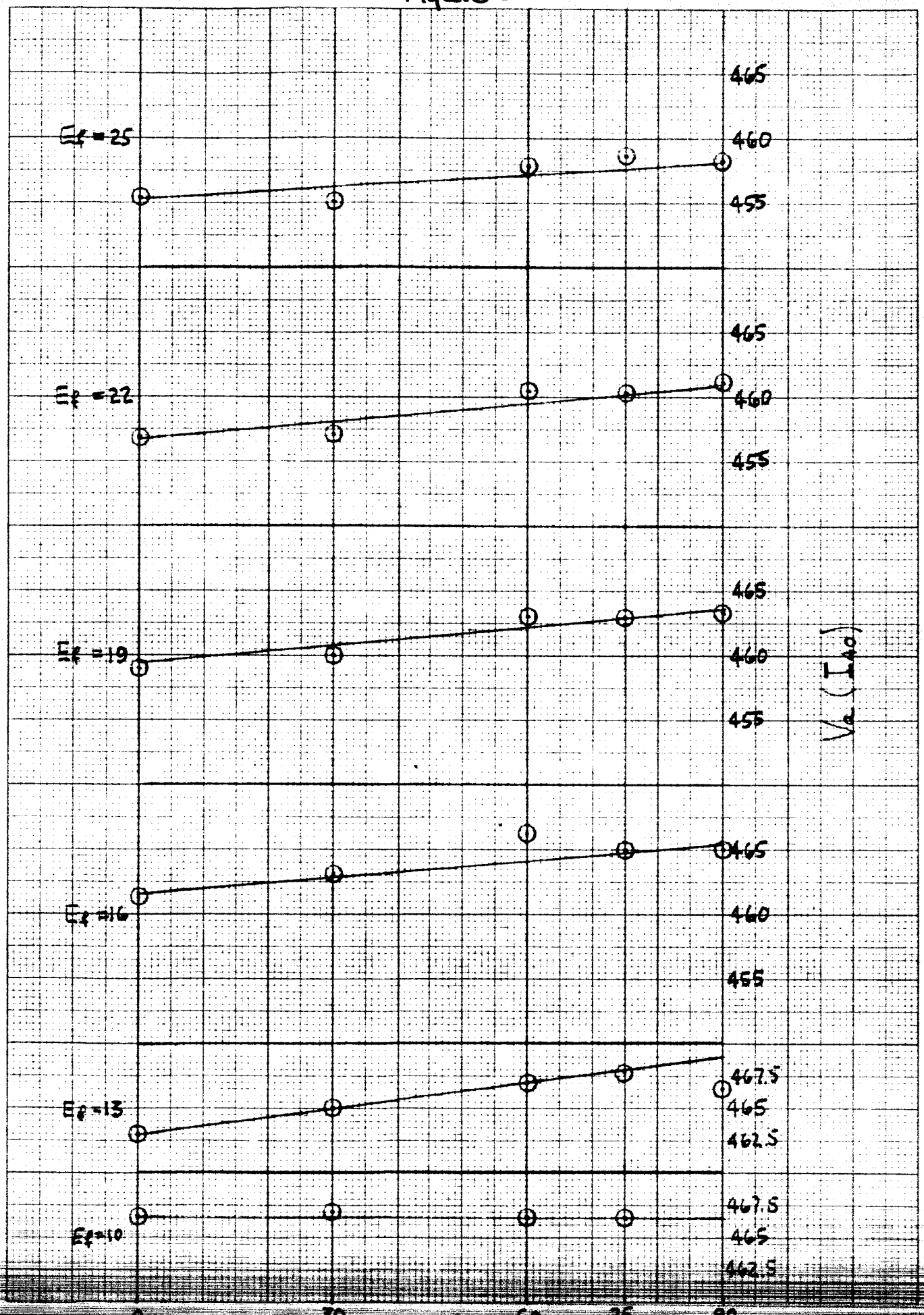

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Figure 9

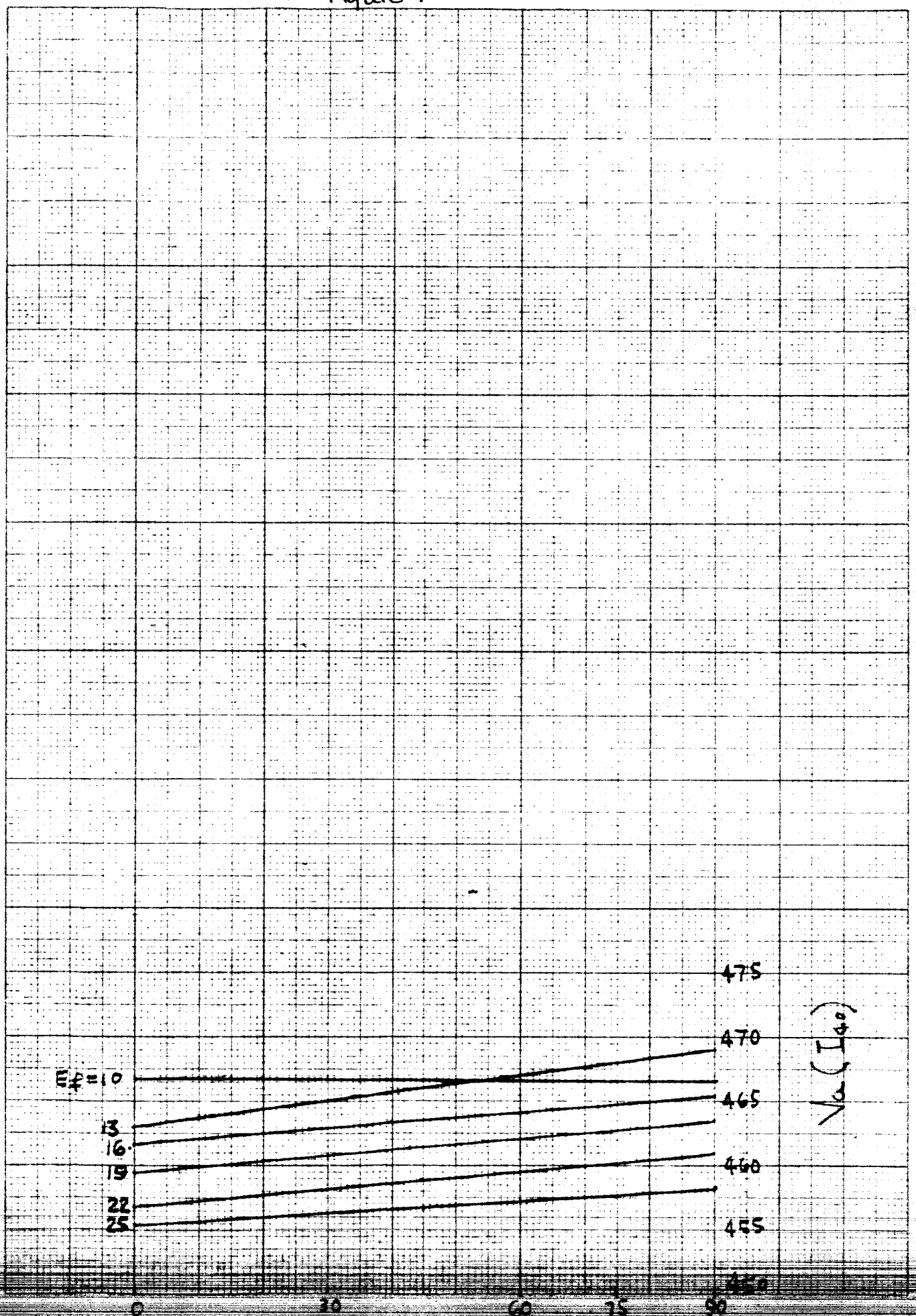

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Figure 10

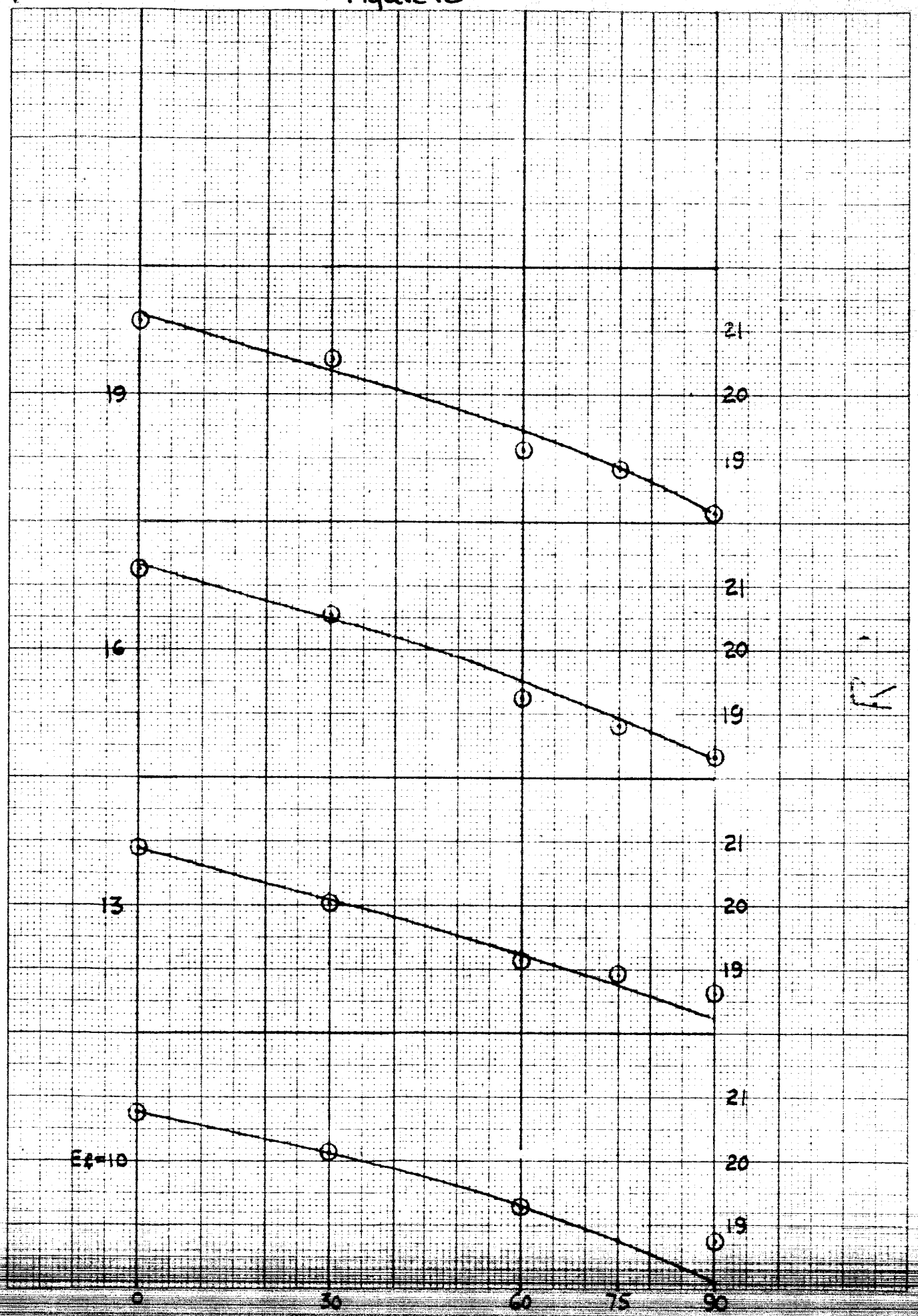

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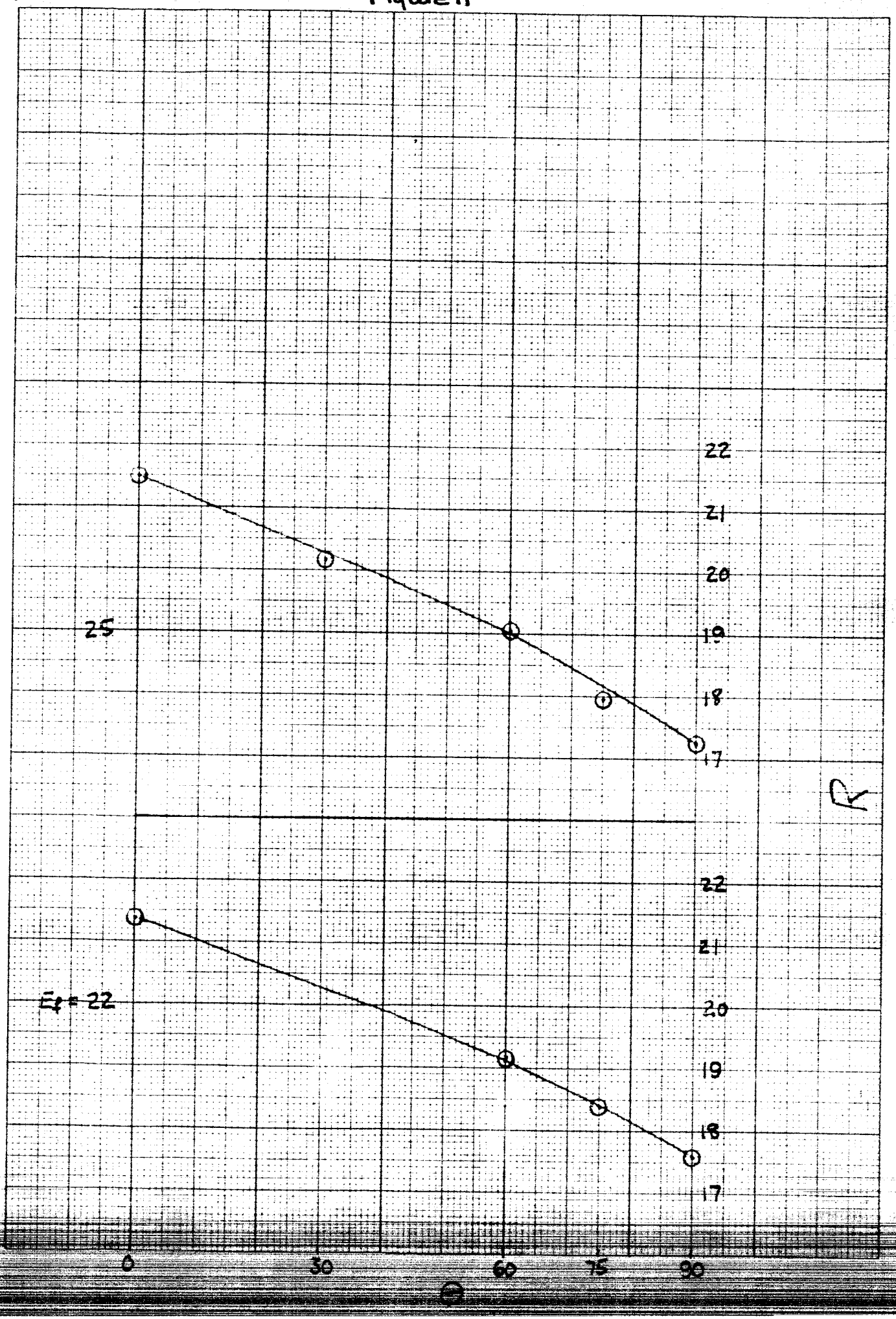
Figure 11



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